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ITALSAT, THE FIRST Ka BAND REGENERATIVE SSTDMA SATELLITE SYSTEM

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ABSTRACT

The paper presents the ITALSAT overall program including description of the two satellite system, the Ka band communication system architecture and services, the L band payload for mobile users and the propagation experiment at 40 and 50 GHz. An overview of the four years of F1 operational utilization is also included.

INTRODUCTION

ITALSAT is the Italian domestic communication satellite system designed to provide digital capacity over Italy. The system will became fully operational when its second flight unit is launched.

The first spacecraft (F1) was successfully launched in January '91. Its primary objective was orbital evaluation of advanced technologies and architecture suitable for a domestic digital communication system and to utilize the spacecraft for operational communication within Italy's telecommunication network. The ITALSAT digital communication system for fixed services is based on an innovative Regenerative Multibeam payload and on a more conventional Transparent payload. Both operate at Ka band (20/30 GHz frequencies). F1 has, also, a propagation package on-board which allows experiments at 20 GHz (mainly for correlation with the existing data) and at 40 and 50 GHz which are the next frequency bands still to be explored for future communications systems.

The second flight unit (F2) has the same on-board Regenerative Multibeam and Transparent 20/30 GHz payloads as F1. In addition, in place of the propagation package, F2 has an L band mobile communication payload, developed by European Space Agency.

1. OVERALL PROGRAM

The program is part of the Italian Space Plan and is managed by the Italian Space Agency (ASI). Main elements of the program are:

- the development and fabrication of: two satellites,
- related ground control facilities (TT&C and Satellite Control Center),
- Multibeam network control center and traffic terminals (only development),
- launch of both flight units,
- in-orbit experimentation and validation of the Multibeam Ka band communication system.

F1 arrived at its final geostationary location (13.2 East) on the 6 th of February '91. It was then transferred from the European Space Operation Center to the Fucino Italsat Control Center for the

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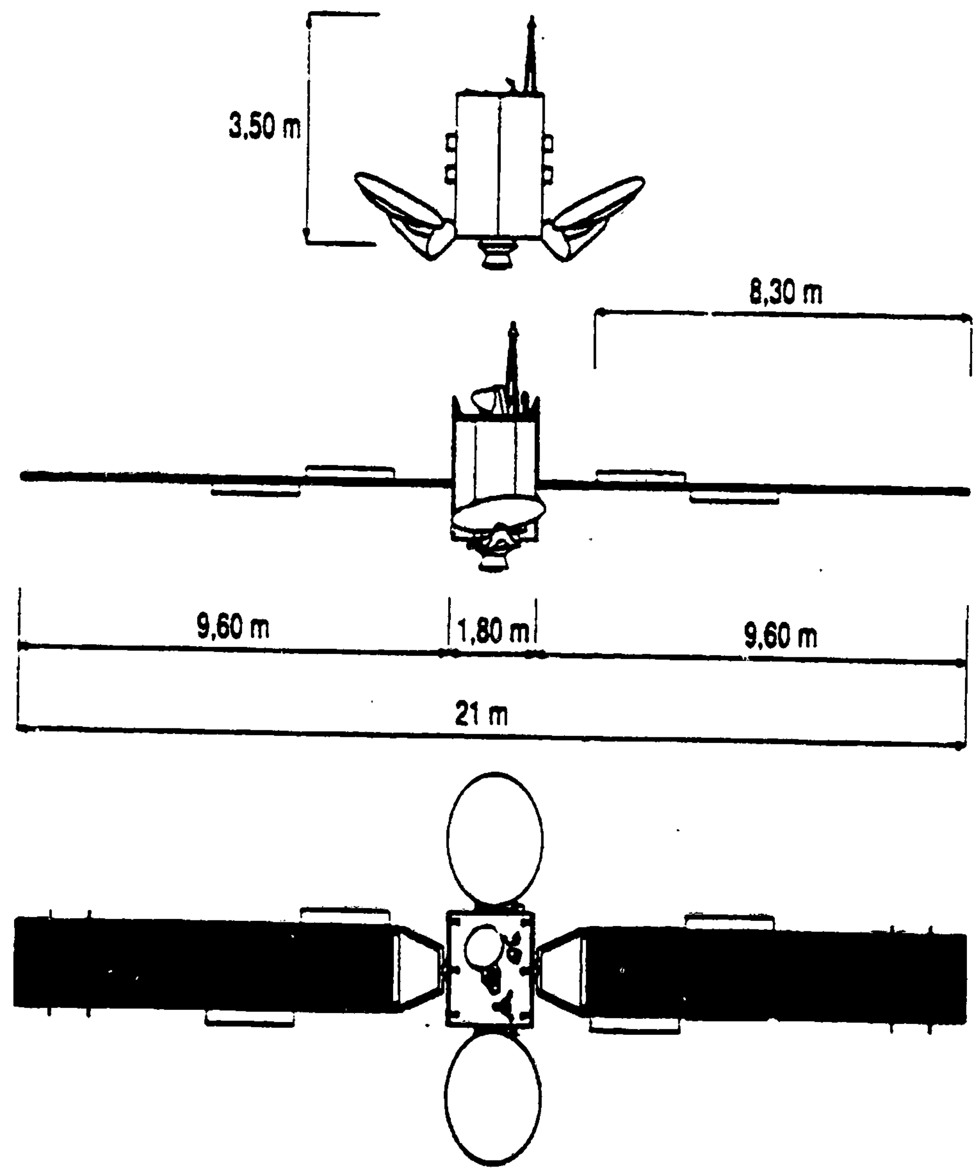
commissioning and experimentation phases. These were successfully concluded by the end of '92. Since early 1993 the Multibeam payload is operating in full integration with the public telephone network while the transparent payload mainly supports VSAT networks.

The second flight unit, which is now concluding the system tests, will be launched in the second quarter of '96. Its initial orbital position will be at 10.2° East. F2 will be commissioned in this orbital position and will start its operative service with the L band mobile service payload while the Multibeam payload will be the in-orbit spare for F1. When F1 reaches the end of its operational life, which is expected by the end of '97, F2 will be moved to 13.2° East to take over the Multibeam payload operations.

The Multibeam and Global beam ground networks have been deployed and are operated by TELECOM ITALIA which is, also, economically contributing to the launch of F2 and to the in-orbit operation of F1 and F2.

The F1 satellite configuration and dimensions are reported in the following schematic:



2. F1 and F2 Ka BAND COMMUNICATION SYSTEM

The ITALSAT flight units F1 and F2 have on-board two communication payloads at 20/30 GHz (Ka band). Both payloads provide coverage of the Italian territory. One by means of six spot beams, so it is called Multibeam payload (MB). The second by means of an elliptical shaped coverage, so it is called Global beam payload (GB).

Multibeam System.

The Multibeam communication system was specifically designed to be integrated with the public telephone network exchanges. The MB capacity is provided in either semi-permanent and/or on-demand modes. Capacity provided in the semi-permanent mode can be changed as needed within a few minutes. This mode is defined as "Traffic Rearrangement". Capacity provided on demand is assigned in real time (DA). The Multibeam system provides the following services:

- Voice at 32 kbit/s with ADPCM (which is compatible with data up to 9.6 kbit/s). The service can be either on demand or in a semi-permanent mode (the DSI technique may be added if required).
- Data at 64 kbit/s (semi-permanent mode).
- Videoconference up to 2 Mbit/s (semi-permanent mode).
- Digital TV up to 70 Mbit/s (semi-permanent mode).

The Multibeam payload has a total capacity of 882 Mbit/s and uses the following techniques:

1. Multibeam antennas with automatic RF pointing control (within 0.03°).
2. Onboard coherent QPSK demodulation.
3. Baseband switching using ECL gate array technology.

The MB system is a BB-SS-TDMA type in uplink (Baseband-Satellite Switched-Time Division Multiple Access) and TDM in down link. The maximum capacity of the MB system is 12,000 32-kbit/s circuits. The DSI (Digital Speech Interpolation) technique can increase this capacity (by a factor of up to 2).
The MB system was conceived to perform different levels of network functions. These functions, in addition to the transmission and traffic rearrangement, are:

- Concentration at earth terminal. When different exchanges, with small traffic bundles, are gathered in the same terminal.
- Variable Origin and Variable Destination (VO/VD). When preassigned spot to spot satellite channels are used by terminals belonging to one spot to set up, on demand, links with terminals belonging to any other spots.

Coverage of Italy is provided by means of six spot beams. Each spot is served on-board by a redundant regenerative repeater. Each repeater receives one up link carrier (30 GHz) and transmits one down link carrier (20 GHz). The carriers are QPSK modulated at 147.456 Mbit/s. The spot to spot connectivity is provided by a synchronous baseband switch matrix. Earth stations belonging to the same spot (up to a maximum of 16) transmit TDMA bursts within 32 msec frame.
The data streams that are received from the six spots, are coherently demodulated and synchronously regenerated. The baseband switch matrix establishes the spot to spot connections according to a designated time plan to form the six synchronous down link streams. The down link frame, of 32 ms has the same burst modularity as the up link. Digital signals are then directly modulated and retransmitted using 20 W TWTAs. The on board switch matrix is controlled by a time-plan which is

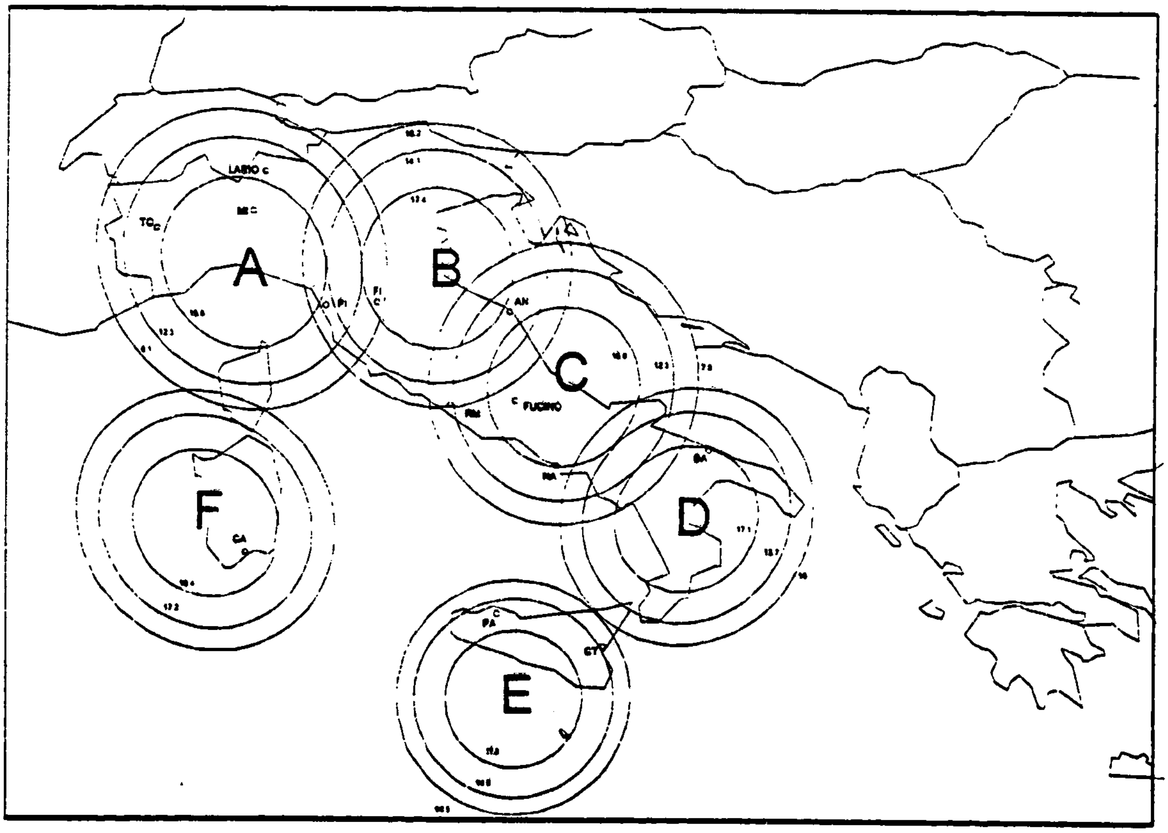
changed through a dedicated service channel transmitted by the Network Control Center in its up link frame.
The up and down link frames are divided into 3072 Frame Units (FU). The FUs are grouped into four different kinds of bursts namely: single channel, four channel, video conference channel and TV channel bursts. The first six FUs of both up link and down link frames are used on the up link to transmit the time plan to the on board switch matrix and on the down link to broadcast the reference burst needed for the Satellite Network synchronization. While the time plan is present only in the frame coming-up from the control center, the reference burst is generated onboard and broadcast in down link to the six spots. The remaining part of the frame is then divided to satisfy the specific service requirements:

- the first part of the frame is used for point-to-point services offered in semi-permanent mode;
- the second part is used for point to multipoint services such as video conferences and bearer service;
- the third part is used for point to point services offered in demand assignment;
- the last part of the frame is used for network overhead and telephone signaling channels.

As indicated above, the duration of each service can be adjusted to satisfy the specific demands, for example, the duration reserved for Demand assignments, can be up to 40% of the frame duration.

Multibeam coverage areas are shown below.

MULTIBEAM PAYLOAD COVERAGE AREAS

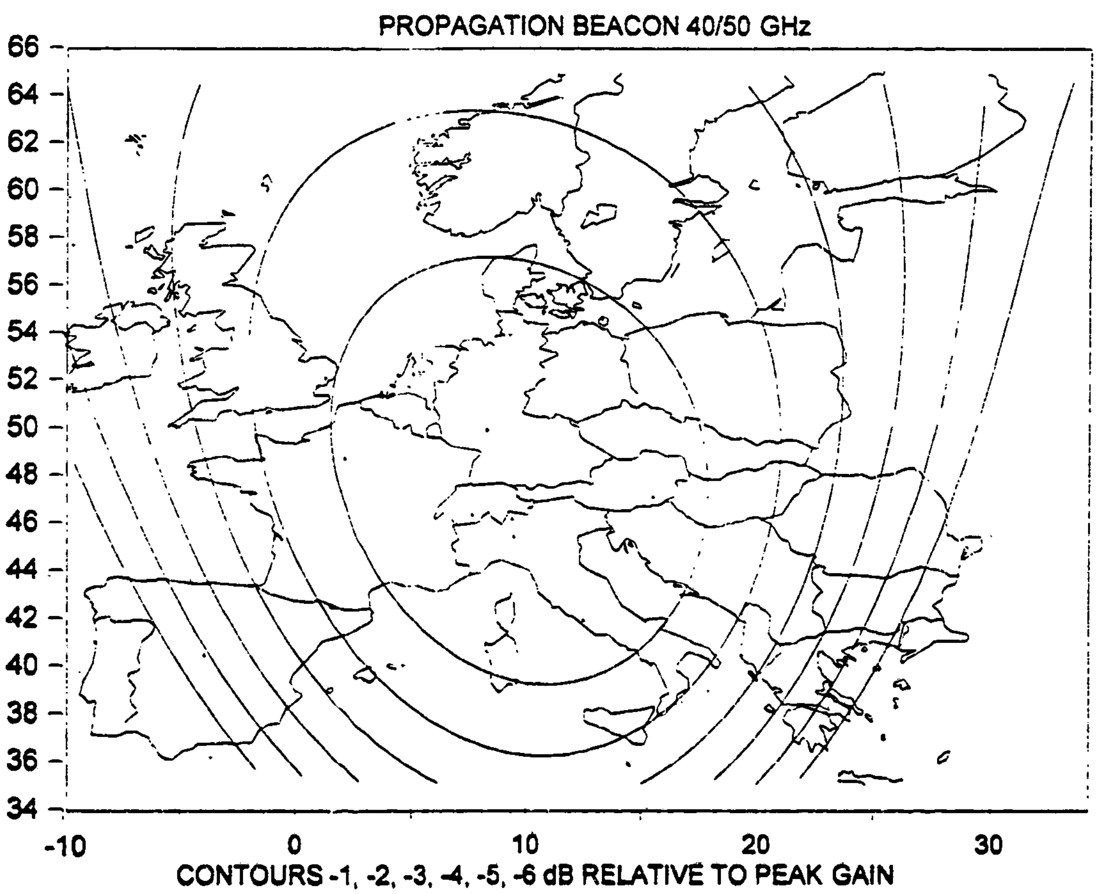


Global Beam payload.

The Global beam payload is composed of three transparent transponders. Each transponder has 36 MHz bandwidth and a 20 Watt RF TWTA. The payload allows analog and/or digital transmissions with customer premise terminals with antenna diameters ranging from 1.2 to 1.8 m and transmitted power from 5 to 25 Watts, depending on the specific application. The service area is centered over Italy, but its enlarged footprint also serves part of central and eastern Europe.

3. F1 PROPAGATION EXPERIMENT

The F1 radio-propagation package extends into the EHF band Italian propagation research which started with domestic SIRIO satellite in the 70's and continued with ESA's OTS and OLYMPUS satellites. ITALSAT's propagation research is the most advanced currently under way for the high frequencies explored. F1 has two beacons on-board at 40 and 50 GHz generated by two redundant beacon transmitters and one beacon at 20 GHz transmitted through the Global beam payload.
Figure shows footprints of 40/50 GHz ITALSAT propagation experiment.



Key features of the 40 and 50 GHz experiment are:

- full coherence of all transmitted signals;
- phase modulation of 40 GHz signal, so as to derive 2 sidebands for the transfer channel amplitude and phase distortion measurements;
- fast commutated linear orthogonal polarization at 50 GHz for complete assessment of the transfer channel polarization matrix;
- wide coverage (most of Europe).

The data acquisition, editing and processing activity is currently in progress. Preliminary results have been partially published. Data on attenuation, depolarization and signal scintillation are available and studies concerning the physical and statistical nature of the depolarization by rain and ice have been conducted. Similarly the phenomenon of signal scintillation due to atmospheric turbulence and clouds has been investigated. Preliminary model-oriented conclusions to be employed in the low-margin telecommunication systems design have been proposed to the scientific community.

4. F2 L BAND PAYLOAD

The payload, called EMS, is designed to provide service for mobile users in European region, North Africa and Turkey. Payload is operating in L band for links (up and down) between mobile users and satellite and in Ku band for links (up and down) between fixed stations and the satellite.
EMS payload transmits and receives L band signals through the two Multibeam antennas. One antenna receives the other transmits, while the Ku band signals are received and transmitted via a dedicated antenna mounted on the satellite top floor. EMS forward link (from ground station to mobile) and the return link (from mobile to ground station) are processed in the IF processor which is performing channellization, filtering and amplification of the signals. The IF processor is divided in two sections: the forward section with three channels of 4MHz each (each 4MHz channel is separately amplified). The return section with three channels of 4 MHz, each subdivided in 4 channels of 1 MHz independently amplified. Two beam forming matrixes are feeding the received L band signals to LNAs and the transmitted L band signals to L band SSPAs. Each of the four redundant LSPAs generates 20 Watt RF. The total radiated power, after combination of the four LSPAs outputs, is 42 dBW which supports up to 300 bi-directional communication channels with mobile terminals using CDMA modulation scheme.

5. PLATFORM

The satellite platform provides the required services (power, attitude control, propulsion, telemetry and telecommand etc.) to the payloads. The platform is three axes stabilized both in transfer and geostationary orbit. Its overall dimensions were defined for dual compatibility with Shuttle and Ariane. Equipment layout was selected in order to optimize: thermal control, radio-frequency interference and units integration. The Multibeam payload is mounted on the North panel while the Global and propagation payloads are installed on the South panel, so that each payload can be independently integrated and tested at panel level. The core of the platform is the central cylinder which houses the two ellipsoidal shaped propellant tanks.

The propulsion subsystem is composed by 8 redundant 22 N reaction thrusters and a 400 N liquid apogee motor, both using the same tankage and propellant: Mono-methyl Hydrazine and Nitrogen Tetroxide (Unified Propulsion Subsystem).

The attitude and orbit control subsystem uses a central microprocessor unit (CLE) which exchanges data and commands with the peripheral units (sensor and actuators) through a serial bus (MACS bus). The CLE processes all data from the sensors and sends the required commands to actuators. The attitude control is performed by reaction thrusters and a pitch bias momentum wheel. The attitude sensing is based on infra-red earth sensors, sun sensors (analog and digital), and a gyro package.

The commands and telemetry subsystem was designed according to ESA standards. Data are distributed by the OBDH bus, which connects the central unit to the remote units of the payload and platform. Some commands (only the critical ones) are directly accessed, by-passing the OBDH bus.

The electrical architecture is based upon a single power supply bus stabilized at 42.5 V in sunlight and 29 V in eclipse. The electrical power is generated, in sunlight, by two solar array wings. Each wing is made up of four panels. During transfer orbit the deployed outboard panel of each wing provides power. During eclipses and apogee motor firing the power is provided by two 30 Ah nickel-hydrogen batteries.

The F1 communication antenna subsystem includes two deployable (for Multibeam payload) and three fixed antennas (one for the Global payload and two for propagation payload) as well as the telemetry and telecommand omni-directional antenna. The fixed antennas are installed on the upper panel together with the telemetry and telecommand antenna. Each Multibeam antenna has the reflector stowed during the launch. The reflector deployment is performed, in orbit, by using a pyro-release device and a deployment mechanism. The Multibeam mission requires a pointing accuracy of 0.03 degrees which is achieved processing an RF sensing signal and commanding a mechanism to move the reflector (in azimuth and elevation) with respect to the satellite body.

The platform of the second flight unit has been upgraded in selected areas. The main changes are relevant to the power, propulsion and thermal control subsystems. The power subsystem is equipped with a new solar arrays and new batteries with increased power capability in order to supply the EMS payload. Two additional small propellant tanks (20 liters each) in series with the two main tanks (417 liters each) have been added to enhance the capability of the propulsion subsystem to support the spacecraft increased mass and orbital life. Active thermal control elements (heat pipes) were added on the South panel to support the substantially higher thermal dissipation of the EMS payload. The F2 MB antennas utilize a new antenna integrated deployment and pointing mechanism which has been recently developed and qualified. This new mechanism has reduced mass with respect to the previous one used on F1.

F1 and F2 platform characteristics are compared in table 1.

6. IN ORBIT EXPERIENCE

F1 operational life started in October '91 at conclusion of the commissioning phase which lasted for 7 months. The purpose of ITALSAT F1 commissioning was to test extensively the performance of the Multibeam payload which, due to its innovative concept, took a rather long time.

A subsequent experimentation phase started with the purpose of operating the Multibeam system in an "operative like" environment. A network of six stations (one in each spot) and a Network Control Center were used to connect the public telephone network through the satellite to obtain qualitative and quantitative verification of its performance. This phase ended in late '92. Several software bugs and hardware anomalies were detected and solved within the ground network during the experimentation phase making the Multibeam communication system ready for operational traffic. Other papers will present the experiences made and the lessons learned with the preoperational utilization of this system which began in early '93. It is important to note that both communication payloads (Multibeam and Global beam) have also been used also to experiment with new communication services such as:

- support to the public mobile cellular telephone network (PMT) in case of RF link congestion, made with a transportable terminal connecting via satellite the Mobile Radio Base with its Mobile switching Center.
- Interactive multimedia applications to navigate and get pictures and data from a remote data base.
- Several telescience and telemedicine experiments were successfully performed connecting remote control rooms with the data sources allowing the remote control of the scientific experiment or medical diagnosis.

CONCLUSION

In conclusion the ITALSAT Ka band telecommunication system has been successfully integrated into the Italian telecommunication networks.
F1 has been operating successfully since January '91. We look forward to ITALSAT F2 launch in mid 1996.

ITS Satellite Platform		F1	F2
GEO Positioning (deg)			
	Stand by		10.2 Est
	Operative	13.2 Est	13.2 Est
Dimensions (H =3.46 m)		N/S, E/W	N/S, E/W
	At Launch	2.29 x 2.74	2.3 x 2.44
	Transfer Orbit	6.32 x 2.74	6.88 x 2.44
	GEO	21 x 6.1	24.03 x 5.89
Mass at Launch (kg)			
	S/C Bus	661	709
	Payloads	291	299
	S/C Dry	952	1008
	Propellant	915	962
	Total	1867	1970
	Tot. at BOL	1119	1190
ORBITAL LIFE			
	years	7	7.5
POWER (Watt)			
for S/C			
	Transfer Orbit	515	535
	G.O. Equinox	1553	2039
	G.O. Eclipse	1102	1357
from S.A.			
	Transfer Orbit	530	600
	BOL.	2070	2700
	EOL Equinox	1760	2220
	Battery	1152	1409

TABLE 1 - Platform Characteristics